13 Risk Mitigation and Performance Criteria

E. Johansen, M. Fry, and T. Moriarty

CONTENTS

13.1 THE ROLE OF RISK MANAGEMENT IN POLLINATOR PROTECTION

The risk assessment paradigm discussed at the SETAC Pellston Workshop articulates a process to measure the effects of a compound against the protection goals of a regulatory authority. When sufficient data are available to reasonably predict that the intended use of a plant protection product is inconsistent with protection goals of a regulatory authority, and the use of that product remains beneficial and desirable to stakeholders, then risk managers may seek to either continue to refine the estimate of risk, through higher tier testing/analyses (if this remains an option), or to bring the estimated risks into line with the protection goals through specific mitigation measures affecting the proposed use of that compound. Regulatory agencies rely upon mitigation to balance environmental protection goals with other (stakeholder) demands and incorporate mitigation into their management decisions. Consequently, the role of mitigation is central to the process for pesticide regulation. With the exception of few scenarios[1], most mitigation includes reducing potential exposure. The regulatory agency may mitigate the potential risk by denying use on a particular crop or use site. However, in most cases, mitigation actions are those which modify the manner in which a product is used.

[1] Certain inert ingredients have been shown to [indirectly] increase the potency of a compound; in addition, specific environmental conditions may also modify the behavior, and therefore the potency of a compound.

Pesticide Risk Assessment for Pollinators, First Edition. Edited by David Fischer and Thomas Moriarty.

BLBS145-c13 BLBS145-Fischer Printer: Yet to Come February 22, 2014 13:22 246mm×189mm

Stakeholders in the process of risk management include regulatory agencies (national and local), chemical producers, distributors, field advisors, and practitioners (including growers and applicators). At the national level, regulatory authorities are charged with registering pesticide products in a manner consistent with their statutory responsibilities. At the local level, for example, state governments in the United States have their own pesticide registration process, which is equally or more protective than the national level. In other scenarios, in France, for example, specific restrictions can be implemented on the basis of specific cropping or pedo-climatic conditions that may be associated with increased potential risk. At the field level, (additional) mitigation actions can be developed, promoted, and implemented by industry experts, crop specialists, beekeepers, growers, and/or pesticide applicators that extend beyond what is legally required by the regulatory authorities (such as through different management programs).

Mitigation language should be specified in a way that allows for consistent (spatial and temporal) implementation. If mitigation language fails to be clear enough for proper, consistent implementation, then inconsistent protection scenarios may result, and the relationship between the regulatory decision and the protection goals may be lost. Clarity and consistent interpretation are also important because the use of a pesticide product inconsistent with the label directions is in many countries considered a violation of the law that may carry with its prosecutorial action. Insofar that the adjudication of the label violation involves investigation by a third party (usually a local regulatory authority such as in the United States) and arbitration by a civil official, the clarity of the intended use and restrictions associated with a product label is necessary in order to establish misuse. Misuse of a pesticide can also result in severe adverse effects on either human health or the environment.

Regulatory authorities directly or indirectly rely upon feedback information to understand whether assessments and decisions actually support stated protection goals. Feedback information may come in different forms, such as research studies, reports of bee poisoning incidents, or targeted monitoring programs. Feedback information can provide insight into how a product is actually used, unforeseen variables that affect the use of a compound, unforeseen effects of a mitigation action, and/or simply whether the mitigation measures are sufficient to ensure the protection goals. Targeted programs (i.e., investigation designs that time information collection with the actual use of the products) can be expensive but provide high quality data. Investigations such as eco-epidemiological analyses such as those described by Susser (2004) may not be as valuable as targeted monitoring programs, but can provide information on one or several co-variables. Information gained through bee poisoning incident reports may lack some information (such as timing of application, application rate, or analytical analysis) that may be useful in establishing that a particular chemical use resulted in an incident, but may provide information on a specific type of product or use scenario that may be anecdotally linked to an incident. In addition, because incident reports frequently rely upon volunteer reporting, it is difficult to know the degree to which incident reports reflect real world conditions. Therefore, a lack of incident reports may or may not be indicative that the intended (directed) use of a product is safe. Conversely, the lack of incident may not represent the extent of events related to a product, that is, the absence of incident reports cannot be reasonable construed as the absence of incidents. Conversely, the presence of limited incidents may not necessarily indicate whether a risk exists with a product. However, a pattern of incidents related to a specific compound, application method, or crop, for example, may be a clear indication of a risk issue. Nonetheless, information from these feedback sources provides multiple lines of evidence that can be used to inform and modify existing or future assessment or management decisions. Additional discussion may be found in a recent European "OPERA" review (Alix et al., 2011).

It is worth noting that when honey bee workers are killed in the field, the loss of these workers may, to a certain extent, be compensated by the growth of the colony, which may continue to grow and reproduce with little or no impact from the kills. Because most non-*Apis* bees are solitary species, where single females build their nests, lay eggs, and forage for pollen and nectar to feed their offspring, the death of a foraging female or even the incapacity to provision her cells results in the cessation of her reproduction (Tasei, 2002). Below is a brief discussion of considerations with respect to pesticide risk mitigation for *Apis* and non-*Apis* bees.

13.2 REGULATORY RISK MITIGATION METHODS

The risk assessment should provide a clear description of the risk (i.e., the likelihood and magnitude of an adverse effect) that needs to be mitigated. Knowledge of the chemical physical properties, environmental fate, and ecological effects of a compound are integrated with an understanding of the use of a compound to provide the information necessary to develop potential mitigation options. Specific characteristics of the risks to be mitigated may include the following:

- Whether the risk is related to acute effects on adult bees, chronic effects on adult bees, adverse effects on larval development, or other effects (such as interactive effects of tank-mixes containing insecticides and fungicides).
- Whether the risk is related to honey bees, other species of bees, or both.
- Whether the risk is related to a particular crop or site being treated, to off-target movement of the pesticide to adjacent crops or blooming weeds where bees may be foraging on nectar and/or pollen, or to other concerns (such as contamination of nesting materials used by non-*Apis* bees).
- Whether the risk is related to a particular application mode (systemic or topical) or method (such as spray, or irrigation).
- Whether or how long the pesticide exhibits hazard to bees following application (referred to as extended residual toxicity (RT) in the United States.

Crops Requiring Pollination by Bees: Central to managing risk of pesticides to bees is controlling potential exposure at the time, or under conditions when bees are (likely to be) present in an agricultural setting. One of the most critical issues for risk mitigation is when bees are present at a site for pollination of the crop (Riedl et al., 2006), which may also include bees foraging on understory bloom or in an adjacent or border area. For crops that require pollination by bees, the primary consideration should be to protect bees from pesticide residues that represent a hazard potential. While every attempt should be made to avoid applications of insecticides and fungicides during the pollination period, use of a plant protection product may be needed (or designed for use) when the crop may be most attractive to bees. When developing risk mitigation statements, there are several mitigation options that could be considered:

- *Product Formulation:* Typically there may be several formulations that could be used to treat a crop/pest combination. To the extent possible, formulations should be those that pose the least threat to bees. Formulations that approximate pollen grains (e.g., some microencapsulated products) in terms of particle size can lead to greater exposure as bees may accumulate the product through their normal foraging activity. However, addition of a sticking agent to a foliar application can potentially reduce transfer from the plant to the bee. Granular formulations are typically considered the least hazardous to bees. Seed treatments also provide limited exposure (similar to granular formulations) provided that dust emission (from abrasion during planting) is properly managed. However, dust particles from seed treatments were responsible for a large number of bee poisoning incidents in Germany during 2008 (Pistorius et al., 2009). Soluble and emulsifiable (liquid) formulations are usually safer to bees than wettable powders. Dust and micro-encapsulated formulations may be more hazardous to bees than other formulations, (or routes). For more information on the relative hazard of different formulations, see Johansen and Mayer (1990).
- *Method of Application:* The application method may also be examined to reduce potential environmental exposure. Generally, ground applications result in less off-target drift to both adjacent areas and the understory than aerial applications. Soil incorporated application methods provide limited environmental exposure (via drift); however, since the compound is available to all the growth

material, this method may lead to pesticide residues to be expressed in understory bloom. With respect to aerial application, droplet size can have a marked effect on the extent of drift; in general, larger droplets are less likely to drift compared to finer droplets.

- *Application Parameters:* Limiting the use rate and frequency of application to the minimum required to effectively control the pest or disease organism. Increased application intervals or reduced application rates may lower potential exposure. Application intervals may be related to residue levels in the field that may represent a potential route of exposure (via uptake by the plant or by contact). Products that have demonstrated synergism may be identified or prohibited by a product label.
- *Understory and Adjacent Areas:* The understory of a crop may represent an attractive source of nutrition for the bees separate from, or in addition to, the cultivated crop; and can be a source of either foliar (e.g., from aerial drift) or systemic (when pesticide residues in the soil are taken up by understory flora) exposure to pesticides applied on field. Potential methods of controlling weed bloom include mowing, disking, flailing, or through use of an herbicide. However, it is important to note that eliminating understory forage (as a source of exposure) also forfeits this material as a source of forage or habitat for both pollinators and arthropod fauna. And consequently not considered a sustainable mitigation measure in some European countries.
- Equally important is control of off-site movement of a pesticide. Buffer zones between application and adjacent areas, particularly if they are attractive to pollinators will reduce potential exposure. Use of low drift spray nozzles, not allow application when wind conditions favor drift onto adjacent crops or weeds that are attractive to bees.
- Windbreaks may also be employed to reduce drift. Avoid seed dust at sowing (low wind conditions, equip drillers with dust reducing devices).
- *Timing of Application and Environmental Conditions:* Applications may be restricted to times when bee activity is expected to be at a minimum. Honey bees do not forage at night (in temperate regions), and do not begin actively foraging until the temperature reaches at least 55°F (12.8°C). In addition, some flowers close at night, consequently, spray is less likely to land on this portion of the plant, further reducing potential exposure to the bee the following day when foraging begins. This risk mitigation technique is only effective if the pesticide has an intermediate residual hazard to bees of 8 hours or less (evening applications only), has a short residual hazard of less than 4 hours (evening or morning applications), or if flowers are closed during applications.
- It should be noted though, that other bee species have slightly different activity times, and high temperatures encourage bees to forage earlier in the day or continue to forage later into the evening than usual. Late evening applications are generally less hazardous to bees than early morning applications; environmental conditions such as temperature and dew point may affect the dissipation of a compound (e.g., slow down), thereby extending a compounds residual toxicity. This mitigation option is likely to be of very limited benefit in tropical regions, since the non-foraging period for honey bees in the tropics is very short when compared with temperate regions. For more information on application timing and environmental conditions, see Johansen and Mayer (1990).
- *Tank-mixes:* Tank-mixing may represent an economical option in pest control. However, care should be taken to understand if there are unforeseen effects to non-target organisms from mixing different compounds in a single application. Tank-mixing certain types of compounds may result in interactive effects that can enhance to toxicity of the mixture to bees, such as in the case of pyrethroids and EBI fungicides. (France has recently prohibited tank-mixes of triazole fungicides and pyrethroids (JORF, 2010).
- *Notification:* Growers may notify beekeepers of anticipated pest control needs. This allows the parties involved to discuss variables and options to reduce potential exposure to bees. While beekeepers may try to protect their stock from an application by covering colonies, doing so for an extended

Author: Please provide bibliographic details for Reference citation "JORF, 2010" or else suggest if this could be deleted from the text.

period of time may be damaging to the colonies, particularly in warm weather. Further, it may be difficult to move managed bees "on demand" since the configuration of the colonies, number of colonies, and the bee activity level effect how quickly stock can be relocated (or protected). (Also, while moving or protecting may be an option for managed bees, it will not protect non-managed bees.)

Crops Not Requiring Pollination by Bees: Pesticide applications to blooming crops, crops with extrafloral nectaries, and pollen shedding crops not requiring pollination that are attractive to bees have also been documented as an important cause of bee poisoning (Riedl et al., 2006). The mitigation options listed above should be considered, but the mitigation statements may need to be modified to address the specific circumstances involved with crops that do not require pollination.

13.3 NON-REGULATORY RISK MITIGATION METHODS

Where limitations exist with regard to the level of risk management that can be reliably and effectively implemented through a national-scale label (regulatory method), implementation of risk management may be possible at the *landscap*e, or field level through best management practices (BMPs) employed by the user (non-regulatory). Alternative or additional methods to mitigate risk to pollinating bees may be used in conjunction with measures identified through the product registration and captured on the product label. Beekeepers, growers, and applicators together with integrated pest management (IPM) agents, agricultural extension agents, crop advisors, and pesticide product representatives can exercise field-level knowledge (i.e., practical experience) to achieve maximum protection for both the grower and the beekeeper. Measures that go beyond the product label reflect local knowledge and relationships which foster cooperation that are often the most effective way to manage potential risks.

Among regulatory and non-regulatory methods to mitigate potential risks, communication and cooperation between growers, applicators, and beekeepers is perhaps the most important tool to reduce risk, and ensure that the needs of all of the stakeholders are met. Growers and beekeepers engage in reciprocal, mutually beneficial endeavors and it is to the advantage of each to anticipate/respect the concerns/needs of the other. Growers can learn the pollination requirements of the crops they grow and plan pest control operations with pollination needs in mind. Growers and advisors can proactively manage routine insect pests by developing and monitoring for economic thresholds to initiate appropriate treatment early to reduce pest population and prevent, avoid, or lessen loss without having to rely on higher application rates/intervals that may represent a risk to bees. Such a program is often less hazardous to pollinators and other beneficial insects as well. Applicators can use their knowledge of local weather patterns to time applications in a way that responds to pest pressure and accounts for bee activity, and/or chemical physical properties of the pesticide product. Through communication with growers and applicators, beekeepers should be familiar with pest control problems and programs, to develop mutually beneficial agreements that better ensure the prudent use of insecticides and fungicides. Beekeepers, growers, crop advisors, and applicators should be aware of the toxicity of products being used, and any residual toxicity characteristics. As discussed previously, depending on the size and location of apiaries and weather conditions, some beekeepers can protect honey bee colonies by covering them with wet burlap the night before a crop is treated with an insecticide that has an extended residual hazard. These covers are typically maintained wet and in place for enough time to provide protection from initial hazards. Honey bee colonies should be clearly marked with identification as this facilitates communication.

Apiaries can be situated to isolate them from intensive pesticide application area and to protect them from insecticide and fungicide drift. Establish holding yards for honey bee colonies at least four miles from blooming crops being treated with insecticides that are highly toxic to bees.

Ridge tops are preferable to canyon bottoms, as pesticides can drift down into canyons and flow with morning wind currents.

13.4 SUGGESTED TECHNIQUES TO MITIGATE RISKS TO OTHER SPECIES OF BEES

13.4.1 Nesting and Moving Bees

While shelters for certain species, such as alfalfa leafcutting and bumble bees can be built to be covered, closed, or removed during insecticide applications to reduce the threat of insecticide drift, most non-*Apis* bees, especially soil-nesting species, cannot be relocated as a protection measure. Many non-*Apis* bees will nest in the ground in orchards and even within row crops (Kim et al., 2006). Squash bees (genus *Peponapis*), for example, frequently nest underground at the base of squash and pumpkin plants within the production fields (Shuler et al., 2005), as do *Melissodes* bees in cotton fields (Delaplane and Mayer, 2000). Therefore, recommendations made to protect honey bees by closing up or moving hive boxes are of little value for economically important wild bees living in and around crop fields and orchards. Similarly, some alfalfa seed producers in the western United States rely on artificially constructed salt flats to aggregate large numbers of ground-nesting alkali bees (*Nomia melanderi*) for pollination (Cane, 2008). The large size of such nesting areas, the long distance these bees can fly (up to 3.2 km (2 miles)), and their potential location away from seed production fields makes it impossible to close off nest entrances to prevent them from foraging in recently sprayed fields.

Blooms of any type, including weedy species that may be available in areas adjacent to the crop site, may serve as nesting sites or as a nutritional source for native pollinators (as it is for managed pollinators as well). To the extent that growers can leave such plants undisturbed and manage pesticide drift, they contribute to the conservation of these native pollinators and the diversity of the farm ecosystem. Approximately 70% of native bees are ground nesters, burrowing into areas of well-drained, bare, or partially vegetated soil. Growers and beekeepers can provide resources for nesting sites for many non-*Apis* species. More information on improving habitat for non-*Apis* pollinators may be found in Vaughan et al. (2007) and Vaughan and Skinner (2008).

13.4.2 Timing of Application

Mitigation of potential exposure through restricting applications to the evening or during periods of cool temperatures was discussed earlier, based upon the premise that honey bees usually do not forage when temperatures are below 13°C (55°F) or between late evening and early morning (Johansen and Mayer, 1990), thus giving pesticides with a short residual hazard more time to become inactive or biologically less available. For example, alfalfa leafcutting bees (*Megachile rotundata*) are nearly inactive at 70°F (21.1°C) and completely inactive at 60°F (15.6°C). Both managed alfalfa leafcutting and bumble bees (*Bombus* spp.) can be safeguarded from potential exposures by removing nests prior to pesticide applications. However, this does not reflect the cooler weather tolerance of some temperate species of non-*Apis* bees, such as *Bombus* spp. and *Osmia* spp., both of which are frequently noted for their ability to forage during cool, inclement weather, as well as earlier and later in the day (Thompson and Hunt, 1999; Bosch and Kemp, 2001). Furthermore, the peak foraging times for bumble bees are very early and late in the day, whereas peak honey bee foraging typically occurs at different periods. Similarly, squash bees (genus *Peponapis*) have been documented to perform a significant amount of pollination in the pre-dawn hours when honey bees are inactive (Sampson et al., 2007). Hence, application of pesticides during the evening, while still preferable, may in fact disproportionately affect certain non-*Apis* species. In some instances, spraying crops that are soon to bloom (e.g., those at budburst) may have a disproportionately higher impact on male solitary bees that emerge before the females and often spend the night in flowers or attached to bud stems.

13.5 PESTICIDE APPLICATION TECHNOLOGIES TO MITIGATE EXPOSURE TO BEES

For compounds that are acutely toxic to bees by contact exposure and a screening-level risk assessment indicates a potential risk to bees via contact exposure, data from a higher-tier test, such as ~~US~~ EPA's Tier 2 study to evaluate the toxicity of a pesticide on foliage (e.g., alfalfa) should be used to determine when products should not be applied (e.g., do not apply when bees are actively foraging). To minimize exposure of bees to pesticides, it is important to be aware of weather conditions, particularly wind speed and direction, and avoid applying during those times. Applications at dusk or late evening or early morning prior to dawn when the majority of honey bees are not actively foraging could help minimize contact exposure, depending on the residual time and bioavailability of the pesticide.

13.5.1 Mitigation for Exposure to Seed Treatment Dust

In order to minimize the emission of abraded seed treatment dust during sowing, particularly when seeds dressed with insecticides that are toxic to bees, the following parameters are considered to be particularly relevant.

13.5.2 Seed Coating Quality

Prior to seed treatment, seeds need to be properly cleaned to remove extraneous debris. Thereafter, care should be taken to minimize loose dust in the seed bag. The use of optimized seed treatment recipes is a key parameter to guarantee a high abrasion resistance of the treated seed, while for some treated seeds (e.g., corn), the use of appropriate stickers and film-coatings will further enhance the resistance of treated seeds to abrasion.

13.5.3 Seeding Technology

When seeds are sown using vacuum pneumatic sowing equipment, the use of deflectors, which direct dust downward into the field being planted, has been demonstrated to reduce off-site dust emission. However, even with deflectors, caution should be taken when using this type of sowing equipment in no-till fields, if blooming weeds are present in the field. In this scenario, dust could be deflected directly onto the flowering weeds. Mechanically operated sowing equipment, as well as those using compressed air, are less prone to emit dust into the environment.

13.5.4 Soil Applied Uses

Crops that are not in bloom often harbor blooming weeds or have blooming cover crops. These blooming plants may represent a potential source of pesticide exposure for both honey bees and non-*Apis* bees if the plants are exposed to soil-applied systemic pesticides. Chemigation systems should be maintained in proper working order to ensure that pesticides will not spray, leak, or run off into areas where potential contamination of blooming plants or water sources for bees could occur. Care should also be taken when making granular applications for the same reasons. These potential routes of exposure are probably best addressed through product stewardship, that requires applicator education and post-registration monitoring.

13.5.5 IPM/Crop Rotation

IPM techniques can contribute to the natural reduction of pests by simply employing techniques that reduce the reliance on the broad application of pesticides. When IPM techniques are used, populations of pests can be more easily maintained below detrimental thresholds, thus reducing the need for pesticide treatments, and thus reducing potential exposures to bees.

13.5.6 Landscape Management

Preserved habitats, refuges, food resource, and the like may reduce the dependence of non-target species on commercially cropped areas (Vaughan et al., 2007). Variables such as the nature of the refuge, the proportion or density, location and management of such areas contribute to the effectiveness of the protected area. Initiatives have been undertaken that illustrate the effect of the implementation of flowering strips on pollinating species (e.g., Operation Pollinator developed by Syngenta, http://www.operationpollinator.com) which could provide a useful basis for further recommendations in the future. Further work is needed to actually quantify the benefit in terms of exposure (drift reduction) and impact of the implementation of habitat for non-*Apis* pollinator species. Eventually landscape-level modeling may be used in support of the design of the landscape elements that may be recommended as mitigation measures.

REFERENCES

Alix A, Adams L, Brown M, Campbell P, Capri E, Kafka A, Kasiotis K, Machera K, Maus C, Miles M, Moraru P, Navarro L, Pistorius J, Thompson H, Marchis A. 2011. *Bee Health in Europe: Facts and Figures.* http://www.pollinator.org/PDFs/OPERAReport.pdf (accessed on January 14, 2014).

Bosch J, Kemp W. 2001. *How to Manage the Blue Orchard Bee as an Orchard Pollinator.* Sustainable Agriculture Network, Beltsville, MD.

Cane JH. 2008. A native ground-nesting bee (*Nomia melanderi*) sustainably managed to pollinate alfalfa across an intensively agricultural landscape. *Apidologie* 39:315–323.

Delaplane K, Mayer D. 2000. *Crop Pollination by Bees.* CABI.

Johansen CA, Mayer DF. 1990. *Pollinator Protection—A Bee and Pesticide Handbook.* Wicwas Press.

Kim J, Williams N, Kremen C. 2006. Effects of cultivation and proximity to natural habitat on ground-nesting native bees in California sunflower fields. *J. Kans. Entomol. Soc.* 79:309–320.

Pistorius J, Bischoff G, Heimbach, U, Stähler M. 2009. Bee poisoning incidents in Germany in Spring 2008 caused by abrasion of active substance from treated seeds during sowing of maize. Hazards of pesticides to bees—10th International Symposium of the ICP-Bee Protection Group. Julius-Kühn-Archiv 423:118–126.

Riedl H, Johansen E, Brewer L, Barbour J. 2006. *How to Reduce Bee Poisoning from Pesticides, PNW 591.* Oregon State University.

Sampson BJ, Knight PR, Cane JH, Spiers JM. 2007. Foraging behavior, pollinator effectiveness, and management potential of the new world squash bees *Peponapis pruinosa* and *Xenoglossa strenua* (Apidae: Eucerini). *HortScience* 42:459.

Shuler RE, Roulston TH, Farris GE. 2005. Farming practices influence wild pollinator populations on squash and pumpkin. *J. Econ. Entomol.* 98:790–795.

Susser E. 2004. Eco-epidemiology: thinking outside the black box. *Epidemiology* 15(5):519–520. doi:10.1097/01.ede.0000135911.42282.b4 http://journals.lww.com/epidem/Fulltext/2004/09000/Eco_Epidemiology__Thinking_Outside_the_Black_Box.4.aspx (accessed on January 18, 2014).

Tasei JN. 2002. Impact of agrochemicals on non-*Apis* bees. In: Devillers J, Pham-Delegue MH (eds), *Honey Bees: Estimating the Environmental Impact of Chemicals.* Taylor & Francis, New York, pp. 101–131.

Thompson HM, Hunt LV. 1999. Extrapolating from honeybees to bumblebees in pesticide risk assessment. *Ecotoxicology.* 8:147–166.

Vaughan, M., Shepherd, M., Kremen, C., and Black, S.H. 2007. Farming for Bees: Guidelines for Providing Native Bee Habitat on Farms. The Xerces Society.

Vaughan, M. and Skinner, M. 2008. Using Farm Bill Programs for Pollinator Conservation, Technical Note No. 78. US Department of Agriculture, Natural Resources Conservation Service and Xerces Society for Invertebrate Conservation.